Schmid ATSS

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-3760

ST — AI — 10226

NASA TT F-8977

MEASUREMENT OF THE IONOSPHERE TEMPERATURE BEGINNING WITH THE TWILIGHT FLUORESCENCE OF ALUMINUM OXIDE

BY

B. Authier,
J. E. Blamont,
G. Carpentier

[FRANCE]

23 OCTOBER 1964

NASA TT F-8977
ST - AI - 10226

MEASUREMENT OF THE IONOSPHERE TEMPERATURE BEGINNING WITH THE TWILIGHT FLUORESCENCE OF ALUMINUM OXIDE

Annales de Géophysique,
~~No. 9,~~ September 1964
T. 20, fasc. 3, 1964.

by B. Authier,
J. E. Blamont,
& G. Carpentier

Several recent observations [1, 2] have shown that the emitters containing barium nitrate (or potassium nitrate) and aluminum, ignited at an altitude of more than 95 km, provided at twilight, by way of optical resonance, an intensive luminosity due to Ba (or K) and AlO.

The fast Na and AlO emitter, which we realized as compact as possible, is based upon that principle.

We manufactured in cooperation with J. Lagrange of the "Centre d'Etudes du Bouchet", a tight emitter containing a mixture of 7 kg of aluminum and 6 kg of sodium nitrate, compressed at 25 kg/cm^2.

Placed aboard a Centaur rocket, fired at Mammaguir on 9 Feb. 1964 at 18 23 hours UT (solar depression $6^{\circ}30'$), this emitter gave at 177 km altitude a very luminous orange and green cloud, visible during the emtire twilight.

Being optically thick, the sodium cloud did not allow to obtain temperature measurements beginning with the width of the doublet D; the twilight fluorescence of AlO gave, to the contrary, a good measurement of kinetic temperature.

---

* Mesure de la température de l'ionosphere a partir de la fluorescence crépusculaire de monoxyde d'aluminium.

We have followed with the aid of a photometer [3], the variation in time of the intensity of sequences $\Delta v = -1.0$ and $+1$ of the transition $\Sigma^+ - \Sigma^+$ of Al O. Each of them was measured by a photomultiplier preceded by an interferential filter and a telescope, whose field, limited by a diaphragm, cut at the center of the cloud an approximately cylindrical volume. We assimilate the cloud to a disk, of which we observe the central part, and this brings us to a problem of plane diffusion. On the other hand, we postulate that the total number N of molecules Al O is constant, which implies that the molecules Al O, formed in the course of the rapid chemical reaction (a fraction of a second)

$$NO_3\,Na + 3\,Al \rightarrow Na + 3\,Al\,O + 1/2\,N_2,$$

do not react with the atmosphere.

The diffusion equation will then be written :

$$n(r, t) = \frac{N}{4\pi\Delta t} e^{-r^2/4\Delta t}.$$

N being the total number of emitters; n (r, t) — the number of emitters at the time t in an element of unit surface situated at the distance r from the center of the cloud; Δ is the diffusion coefficient.

We have for the observed entire central disk :

$$n(t) = \int_0^r \frac{N}{4\pi\Delta t} e^{-r^2/4\Delta t}\, 2\pi r dr$$

$$n(t) = N\left(1 - e^{-\frac{2\pi r^2}{4\Delta t}}\right)$$

The telescopes' field was inferior to $40'$, and $r \leq 500$ m; on the other hand $\Delta < 10^{10}$ and, 1 minute after the emission, we may write

$$n(t) \sim N\frac{\pi r^2}{2\Delta t}.$$

If the cloud is optically thin, n (t) is proportional to the lighting. It may be seen in Fig. 1 that the curves 1 and 3, corresponding to sequences $\Delta v = -1$ and $+1$, are hyperbolae indeed, which justifies our hypothesis on the stability of Al O, and shows that the cloud was optically thin for these sequences; on the other hand, the

lighting of the sequence $\Delta v = 0$ (curve 2) does not follow immediately a hyperbolic decline; this sequence was saturated in the course of the first minutes following the emission.

MEASUREMENT OF TEMPERATURES

We have already given the principle of our measurements and described the spectrographs S.G.O. and R.E.O.S.C., utilized in [3, 4]. Besides, we disposed of a monochromator and of a two-way monochromator-photometer, whose results are now being processed

1) Vibration Temperatures

a) Spectrograph REOSC.-

We obtained two utilizable spectra offering the characteristic transition bands $\Sigma^+ - \Sigma^+$ of Al O. Table 1 hereafter gives the intensity ratio of the band heads of the sequences $\Delta v = -1$ and $\Delta v = +1$, and also the corresponding temperatures.

TABLE 1

	Spectre n° 1	Spectre n° 2
Chronologie	H + 2′ à H + 5′	H + 6′ à H + 30′
Séquence $\Delta v = -1$		
Bandes : 0 — 1	100	saturée
1 — 2	51	100
2 — 3	21	33
Température	$\theta = 650 \pm 100$	$\theta = 580$ °K ± 100
Séquence $\Delta v = +1$		
Bandes : 1 — 0		100
2 — 1	inexploitable (*diminued*)	40
3 — 2		9
4 — 3		1,6
Température		$\theta = 700$ °K ± 75

(H : instant d'apparition du nuage — 18 h 26′34″).
time of cloud appearance

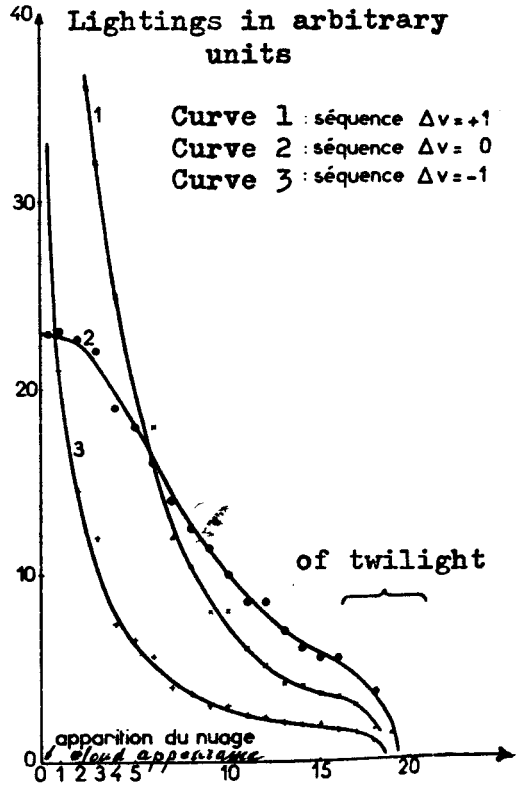

Fig. 1

We have also measured on the sequence $\Delta v = +1$ of the spectrum No. 2 the ratio of planimetric areas of this sequence's bands by extrapolating the end of ranches P, so as to take account of the overlap (Fig. 2). We have found:

../..

Bands	1 — 0	2 — 1	3 — 2
areas	100	42	11

say, a temperature of 750° K, which justifies experimentally the validity of the measurements made by comparing the intensity of band heads (remark by D. C. Tyte [5]).

b) Spectrograph S.G.O. - 19 spectra were taken. These spectra offer sequences $\Delta v = -2, -1, 0$ and $+2$ of the transition $\Sigma - \Sigma$ of AlO and the sodium doublet. Two of them [*], taken from the cloud's periphery, also offer at λ 3.961.5 Å the band 0 — 0 of the transition $^1\Pi - {}^1\Sigma$ of the molecule AlH. We measured ligthing ratio of the band heads 1 — 0 and 2 — 1, plotted as a function of time in Fig. 3, on 10 of our spectra.

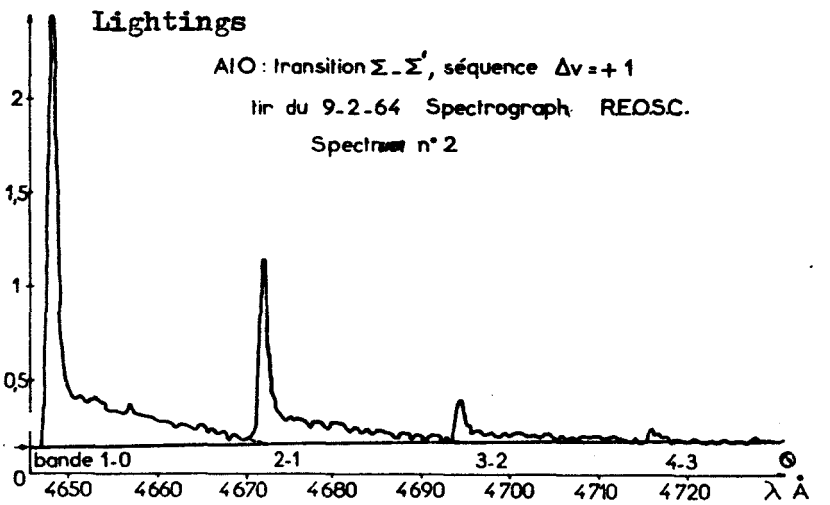

Fig. 2

c) Type- Ebert and Fastie Monochromator [6]. This device includes :

— a dispersive system constituted by a net of 600 strokes/mm of 100 mm in diameter (5000 A in the 1st order),

— a mirror 300 mm in diameter,

— a receiver composed of a photomultiplier EMI with a tri-alcaline layer, cooled by the Pelletier effect,

— an inlet and an outlet slot.

[*] insert ;
...the resonance line of Al and at λ 4.242 Å ....

The scanning of the network is assured by a two-phase synchronous motor with two-way operation (1000 Å/minute).

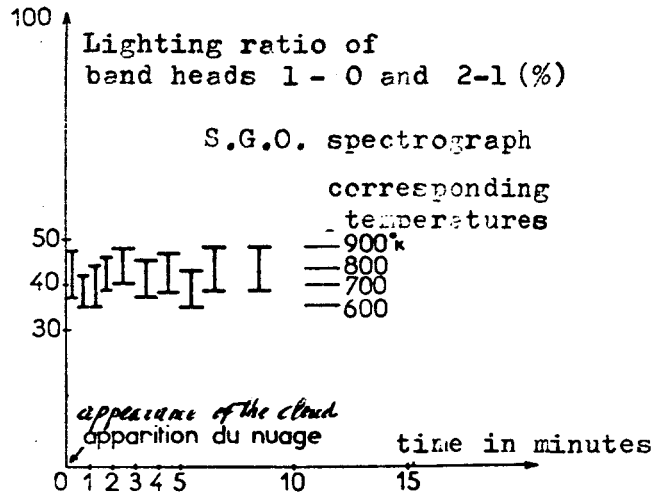

Fig. 3

This device has given us every 45 seconds a spectrum of sequences $\Delta v = -1$ and $+1$, of which we give an example in Fig. 4 with a 2 Å resolution. The lighting ratios of the band heads of the sequence $\Delta v = +1$ and of planimetric areas on enlargment of these sequences are summarized in Fig. 5. The coincidence of these two measurements confirms the remark made in regard of spectra obtained with the spectrograph REOSC.

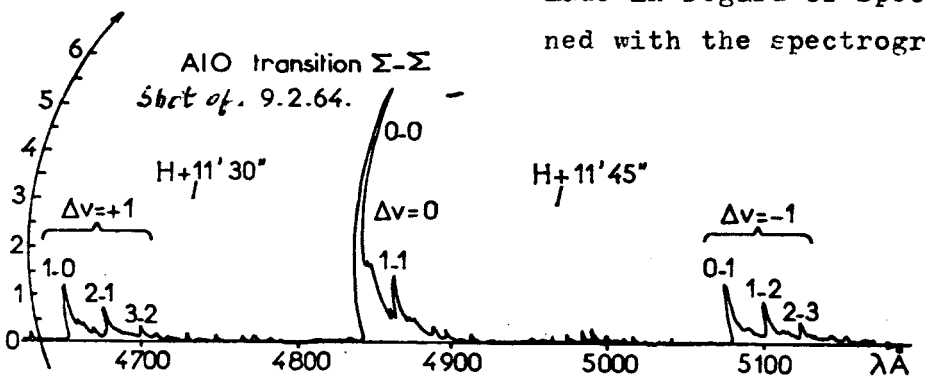

Fig. 4

The measurements made over the sequence $\Delta v = -1$ are unexploitable, as being too dispersed.

2) Rotation Temperature

Because of cloud's optical thickness, only measurements made 4 minutes after the cloud appearance are valid.

The comparison of the branch P of the band $0 - 0$ of the 2nd spectrum obtained with the aid of the REOSC spectrograph with the

calculated theoretical profiles, gives a temperature comprised between 600 and 700° K.

For the monochromator registrations, we have measured the ratio of the intensity maximum of the branch P of the band 0 — 0, to that of the minimum, which we constantly find at 4.862 ± 1.5 Å. The values of this ratio and the corresponding temperatures are plotted in Fig. 6. The good reproductiveness of the measurements does not exclude the possibility of a systematic error.

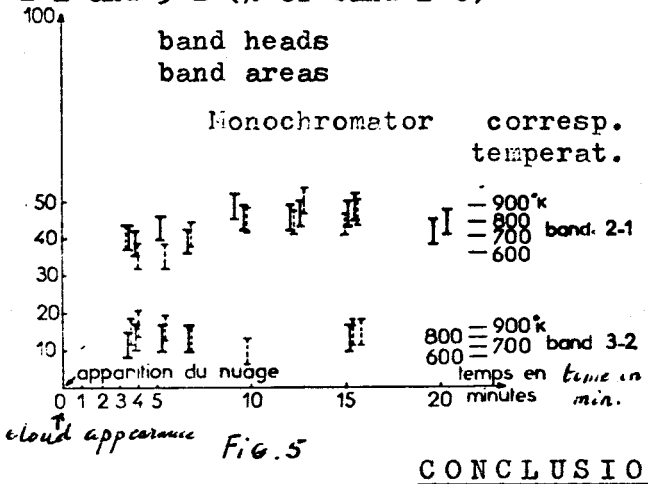

Fig. 5

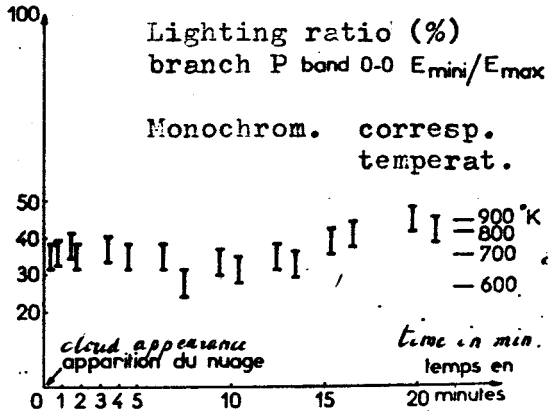

Fig. 6

CONCLUSION

The good agreement of our measurements made by two methods with different devices allows a precise measurement of the temperature at 177 km :

$$\theta = 750 \pm 50^{\circ} K.$$

The payload utilized, easy to realize, must allow a simultaneous measurement of the temperature over the width of the sodium doublet by nine tenths of sodium nitrate load by potassium nitrate.

*** THE END ***

Manuscript received on
23 May 1964.

ST - AI - 10 226

REFERENCES

[1] ARMSTRONG E. B., 1963, *Planet Spac Sci.*, 11, 743. 1963

[2] AUTHIER B., Rapport interne (1963) Service d'Aéronomie du C. N. R. S. 1963

[3] AUTHIER B., 1964, thèse 1963 à paraitre *Annales de Géophysique*, 20, t. 4. 1964

[4] AUTHIER B., BLAMONT J. E., CARPENTIER G., 1962, *C. R.*, 255, 1974 ; 1963, *C. R.*, 256, 3870.

[5] HEBERT G. R., TYTE D. C., Communication personnelle (preprint Proceeding of the Physical Society).

[6] CHABBAL R., JACQUINOT P., 1961, *Rev. Optique*, 40, n° 4, 157. 1961.

Contract No. NAS-5-3760

Translated by ANDRE L. BRICHANT
at Consultants & Designers, Inc.
Arlington, Virginia
23 October 1964

DISTRIBUTION

Goddard Space F. C.

600	TOWNSEND	
610	MEREDITH	
	SEDDON	
611	McDONALD	
612	HEPPNER	
613	KUPPERIAN	[3]
614	LINDSAY	
	WHITE	
615	BOURDEAU	[2]
	BAUER	
	JACKSON	
	AIKIN	
640	HESS	[3]
641	HARRIS	
643	SQUIRES	
660	GI for SS	[5]
651	SPENCER	
	NEWTON	
	BRACE	
252	LIBRARY	[5]
256	FREAS	

NASA HQS.

SS	NEWELL, CLARK
SP	STANSELL
SG	NAUGLE
	SCHARDT
	SCHMERLING
	DUBIN
SL	LIDDEL
	GAUGLER
	FELLOWS
	HIPSHER-HOROWITZ
SM	FOSTER
	ALLENBY
	TROMBKA
RTR	NEILL
ATSS	SCHWIND
	ROBBINS
AO-4	

OTHER CENTERS

AMES R.C.

SONETT [5]
94035 [3]

LANGLEY R.C.

160 ADAMSON
213 KATZOFF
O'SULLIVAN
235 SEATON
MACE
185 WEATHERWAX [2]

LEWIS R.C.

A. POTTER

UCLA

COLEMAN

UC BERKELEY

WILCOX